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A Parylene Temporary Packaging Technique for MEMS Wafer Handling

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Abstract

This paper presents a wafer-level temporary packaging technique utilizing a chemical vapor deposited (CVD) poly-(p-xylylene) polymer Parylene film, and oxygen plasma etching. As a test case, released, unpackaged accelerometers made in a SiGe MEMS above IC technology were coated with two different types of Parylene, Parylene N and Parylene C respectively, as a dicing protection. Oxygen plasma is used to etch the Parylene and to release the freestanding structures after dicing. The final releasing results are compared, and Parylene N turns out to be the best material for temporary packaging. The devices are electrostatically characterized after the Parylene coating. The results demonstrate the feasibility of using Parylene as a temporary protective material for both metal and semiconductor MEM devices, to prevent any damage during subsequent wafer handling and dicing.

Keywords: Parylene; temporary packaging; MEMS; wafer handling;

1. Introduction

Wafer level protection techniques, prior to dicing, can have an enormous impact on cost, yield and reliability [1-4].Wafer-level temporary packaging is crucial in case permanent wafer-level packaging is not foreseen (or possible), to prevent fragile MEMS devices from damage during dicing and handling. Several temporary packaging methods have been proposed in literature, including Thermo-Compressive Packaging [5] and the use of glass caps laminated with UV-sensitive tape [6]. In this paper, we report on the use of a CVD deposited Parylene layer as a suitable wafer-level packaging candidate. The low

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temperature CVD process can ensure the overall coverage of each surface of the free-standing structure. The MEM device can thus be protected during wafer handling and dicing. As the packaging is only temporary, a clean releasing process needs to be foreseen. Oxygen plasma etching is used to strip the Parylene layer thoroughly. The demonstration device will be characterized electrostatically.

2. Experimental details

2.1. Parylene deposition

Two types of Parylene are studied: Parylene C (having one chlorine group per repeat unit) and Parylene N (polymerized from the pxylylene intermediate).Coating parameters are optimized to obtain the mandatory Parylene thickness to fully cover the already released structures. The devices tested are in-plane SiGe capacitive accelerometers with 110µm long comb shaped fingers and a 3 µm free-standing gap. The distance between the adjacent fingers is 1 µm and the smallest gap is 500nm (Fig. 1).

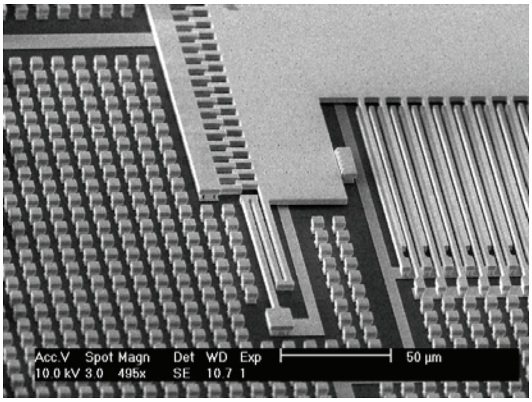


Fig. 1. SEM view of the SiGe MEMS inertial sensor before the Parylene coating

The devices are coated with Parylene N and Parylene C as described in Table 1(PPCS type PP220 plasma Parylene coating system). The Parylene CVD deposition is known to conformally coat the entire free surface of the device. Figure 2 shows the device after the Parylene coating. The protective Parylene layer should prevent the freestanding parts from capillary attraction and dicing debris. After the deposition process, the samples are treated in an ultrasonic water bath for 10 minutes, to simulate the environment similar to that of the wafer dicing process. No visible damage could be observed at this stage, indicating a solid fixation of the MEMS' vulnerable structures.

Table 1. The CVD coating conditions of the Parylene C and the Parylene N.

Parylene Type	Dimer evaporation step 1	Dimer evaporation step 2	Temp. monomer	Temp. chamber
N	125 ºC 1h	130 ºC 1/2h	660 ºC	80 ºC
C	130 ºC 1h	135 ºC 1/2h	720 ºC	130 ºC

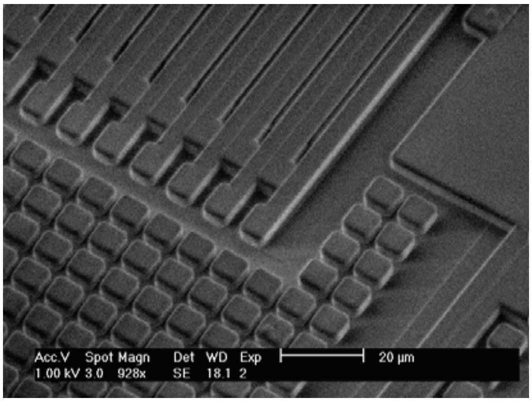
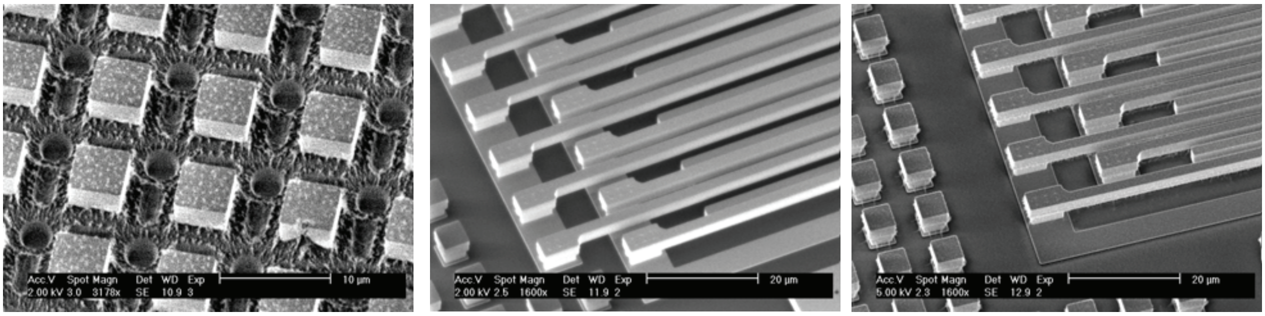


Fig 2. SEM view of the Parylene N coated device, all movable structures are solidified by the coating

2.2 Parylene removal

In order to remove this temporary protective layer, oxygen plasma is used. (Plasma Technology 80 series, 100W, 100mtorr, 30sccm oxygen flow, sample temperature 40°C, 4 hours) Figures 3 (a) and (b) show the Parylene N-coated device during and after the oxygen plasma ashing step. These SEM pictures reveal that Parylene N can be cleanly stripped. On the contrary, some particles were still observed after stripping Parylene C (Figures 3 c)

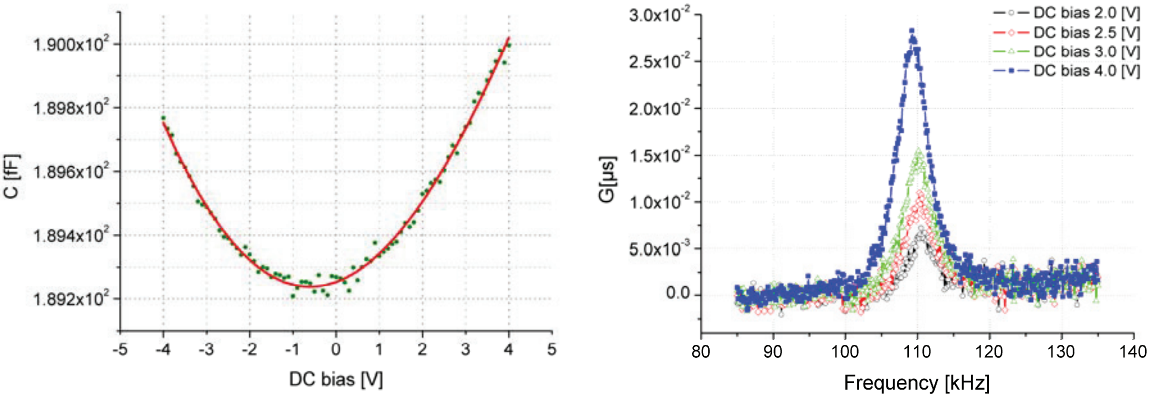


(a) (b) (c)

Fig. 3. (a) SEM view of the dummy islands with the partially etched Parylene N by oxygen plasma; (b)SEM view of the sensing fingers after the oxygen plasma release of the Parylene N coating; (c) SEM view of the sensing fingers after the oxygen plasma release of the Parylene C coating;

3. Results and discussion

Both a C-V test and a resonance frequency test have been performed after Parylene N deposition and removal. Fig. 4 (a) and (b) show the results of the electric characterization of the device after stripping the Parylene. The results indicate that the sensing fingers of the device have a DC response and that the resonance frequency responses to the electrostatic actuation. The results prove that the free standing fingers of the device function again after the temporary package removal. Since the etching time is determined by the under-etch surface beneath the MEM structure, a smaller under-etch surface will reduce the release time. The thickness of the Parylene layer is determined mainly by the time duration when the sample temperature is lower than the polymerization threshold temperature during the CVD process. If precise surface coverage is needed, a system with direct sample temperature control can be foreseen.



(a) (b)

Fig 4. (a) Electrostatic characterization after temporary packaging and release, using a DC voltage sweep from -4V to 4 V; (b) Conductance plot measured after temporary packaging and release to determine the resonance frequency.

4. Conclusions

This paper presents a novel temporary packaging method for MEM devices, by using Parylene deposition and an oxygen plasma release process. This temporary packaging method can be used for a variety of MEM devices. Since the process has a low thermal budget, it is also suitable for CMOS compatible MEM structures. A SiGe capacitive sensor is used here as a demonstration device. Two kinds of Parylene coating have been implemented. The device experienced 10 minutes of ultrasonic water bath after the Parylene coating. Both the C-V curve and the resonance frequency test indicate that the sensing fingers of the device survived the harsh ultrasonic treatment and respond properly after the oxygen plasma strip. Hence, this work proves the feasibility of utilizing the Parylene as a temporary protective material for most wafer-level released MEM structures that require dicing and handling.

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